



US005970499A

**United States Patent** [19][11] **Patent Number:** **5,970,499**

Smith et al.

[45] **Date of Patent:** **Oct. 19, 1999**

[54] **METHOD AND APPARATUS FOR  
PRODUCING AND ACCESSING COMPOSITE  
DATA**

[76] Inventors: **Kurt R. Smith**, 3400 Eldorado Springs  
DR., Boulder, Colo. 80303; **Richard D.  
Bucholz**, 3 Kingsbury Pl., St. Louis,  
Mo. 63112; **Timothy J. Schaewe**, 200  
S. McCaslin Blvd., #100, Louisville,  
Colo. 80027

[21] Appl. No.: **08/832,688**

[22] Filed: **Apr. 11, 1997**

[51] Int. Cl.<sup>6</sup> ..... **G06F 17/30**

[52] U.S. Cl. .... **707/104; 707/102**

[58] Field of Search ..... **707/102, 6, 104,  
707/3**

[56] **References Cited**

**U.S. PATENT DOCUMENTS**

4,644,582	2/1987	Morishita et al.	382/6
4,722,056	1/1988	Roberts et al.	606/130
4,879,668	11/1989	Cline et al.	345/424
4,958,283	9/1990	Tawara et al.	382/131
4,987,412	1/1991	Vaitekunas et al.	340/721
5,005,126	4/1991	Haskin	378/4
5,027,422	6/1991	Peregrim et al.	382/48
5,048,103	9/1991	Leclerc et al.	382/44
5,099,846	3/1992	Hardy	600/407
5,241,472	8/1993	Gur et al.	707/540
5,261,404	11/1993	Mick et al.	600/425
5,272,625	12/1993	Nishihara et al.	707/1
5,274,551	12/1993	Corby, Jr.	600/433
5,284,142	2/1994	Goble et al.	600/547
5,291,401	3/1994	Robinson	382/132
5,309,356	5/1994	Nishide et al.	382/131
5,353,220	10/1994	Ito et al.	600/437
5,383,454	1/1995	Bucholz	600/429
5,402,337	3/1995	Nishide	345/426

5,465,378	11/1995	Duensing et al.	707/529
5,483,606	1/1996	Denber	382/294
5,490,221	2/1996	Ransford et al.	382/130
5,531,227	7/1996	Schneider	600/425
5,531,520	7/1996	Grimson et al.	382/131
5,568,384	10/1996	Robb et al.	707/552
5,581,638	12/1996	Givens et al.	382/294
5,615,112	3/1997	Liu Sheng et al.	707/104
5,633,951	5/1997	Moshfeghi	382/154
5,682,526	10/1997	Smokoff et al.	707/104
5,734,915	3/1998	Roewer	707/512
5,740,428	4/1998	Mortimore et al.	707/104
5,809,497	9/1998	Freund et al.	707/2
5,826,237	10/1998	Macrae et al.	705/2

**OTHER PUBLICATIONS**

Perry, et al., Emission and Transmission Spect Data Combination in Interactive 3D Image Presentation, *The Journal of Nuclear Medicine*, May 1989, p. 835.

Tsui, et al., Three-Dimensional Display Methods for Image Data Obtained with Spect, *European Journal of Nuclear Medicine*, Aug. 1989, p. 639.

(List continued on next page.)

*Primary Examiner*—Wayne Amsbury

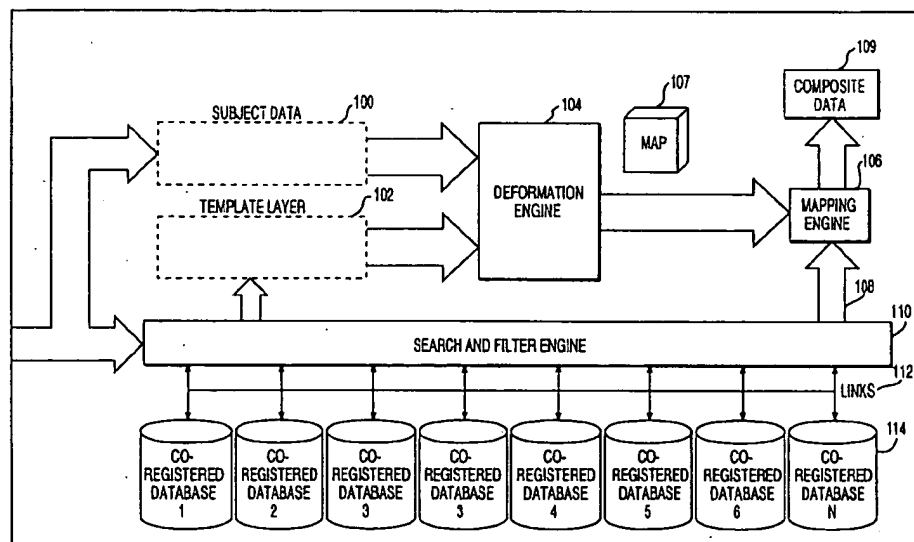
*Attorney, Agent, or Firm*—Finnegan, Henderson, Farabow, Garrett & Dunner L.L.P.

[57]

**ABSTRACT**

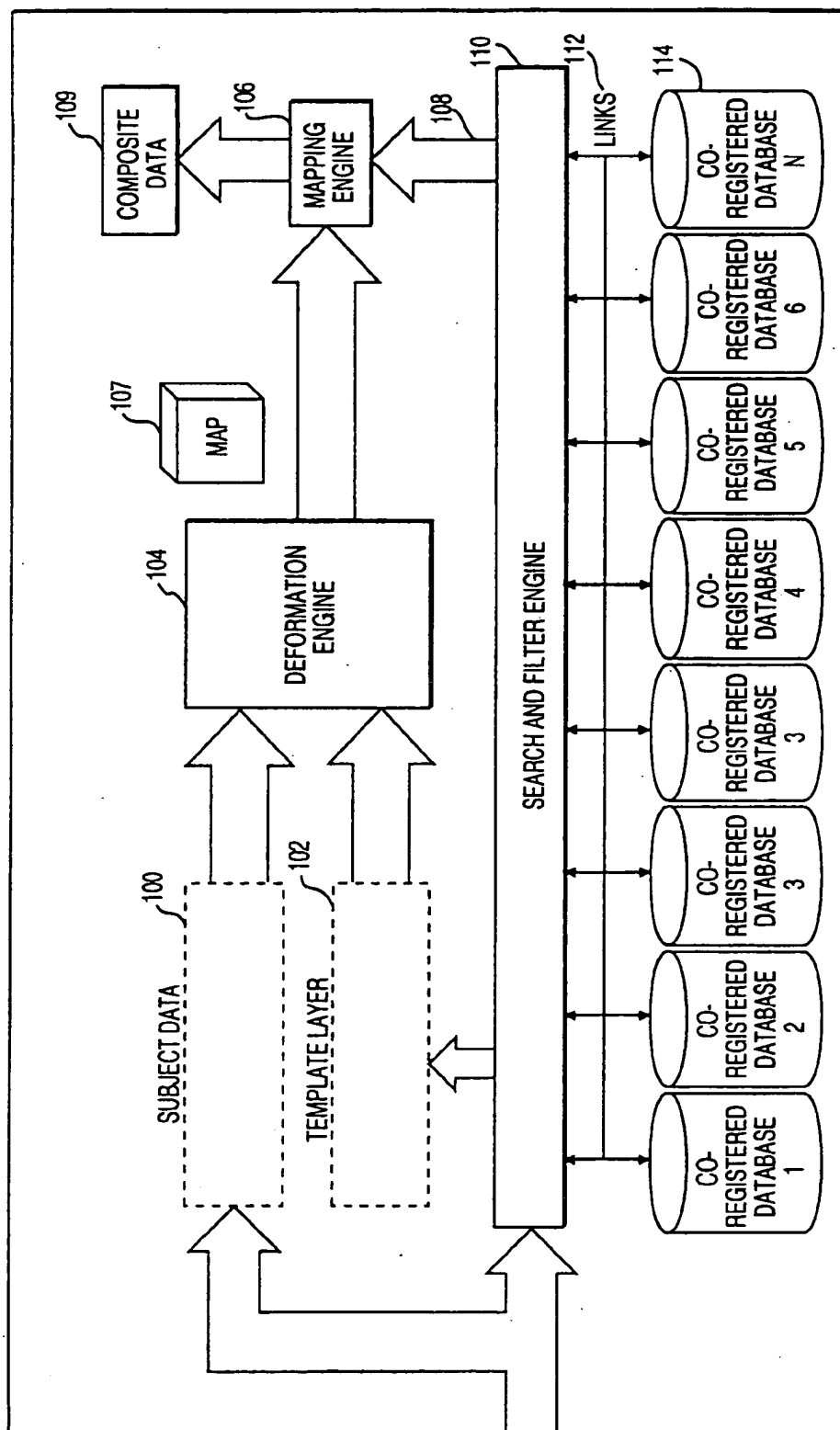
An apparatus and method for producing composite data by a server computer involves deforming a template creating a mapping relationship between co-registered data and subject data, filtering the co-registered data, and mapping this filtered co-registered data according to the mapping data. A client computer requests the composite data from the server computer and transmits the subject data to the server computer. The client presents the received composite data to an operator and monitors the operators use of the composite data.

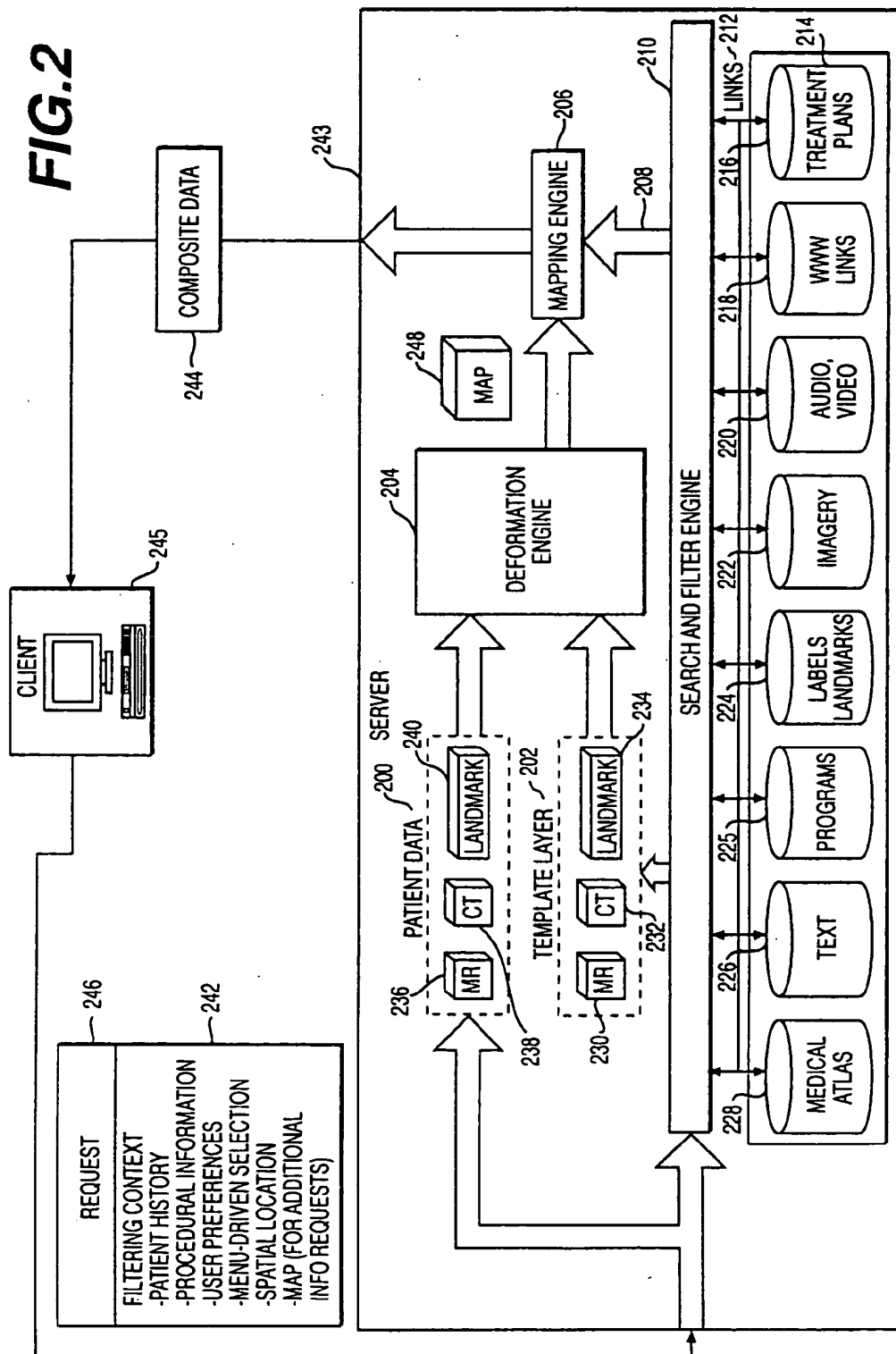
**74 Claims, 7 Drawing Sheets**

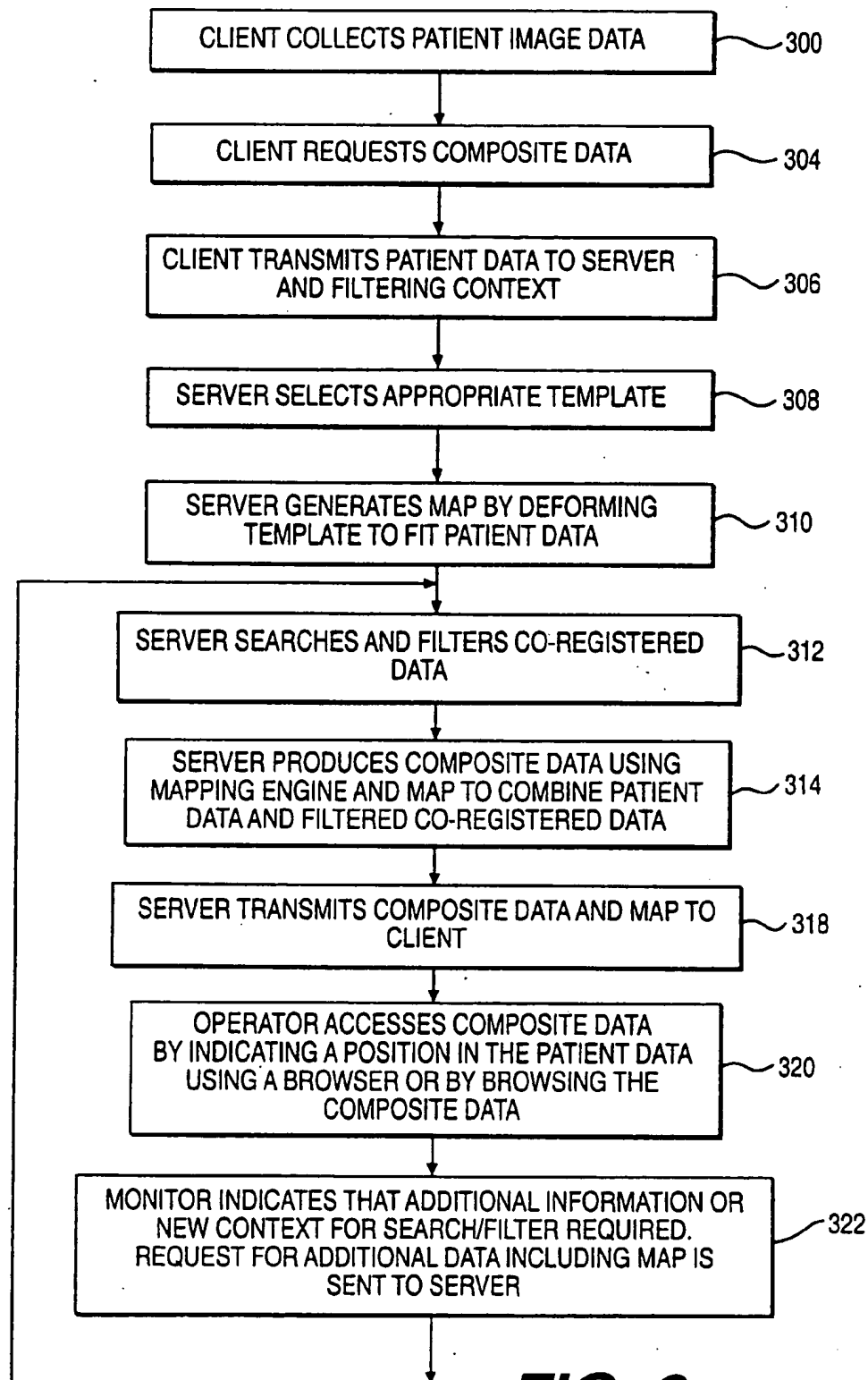


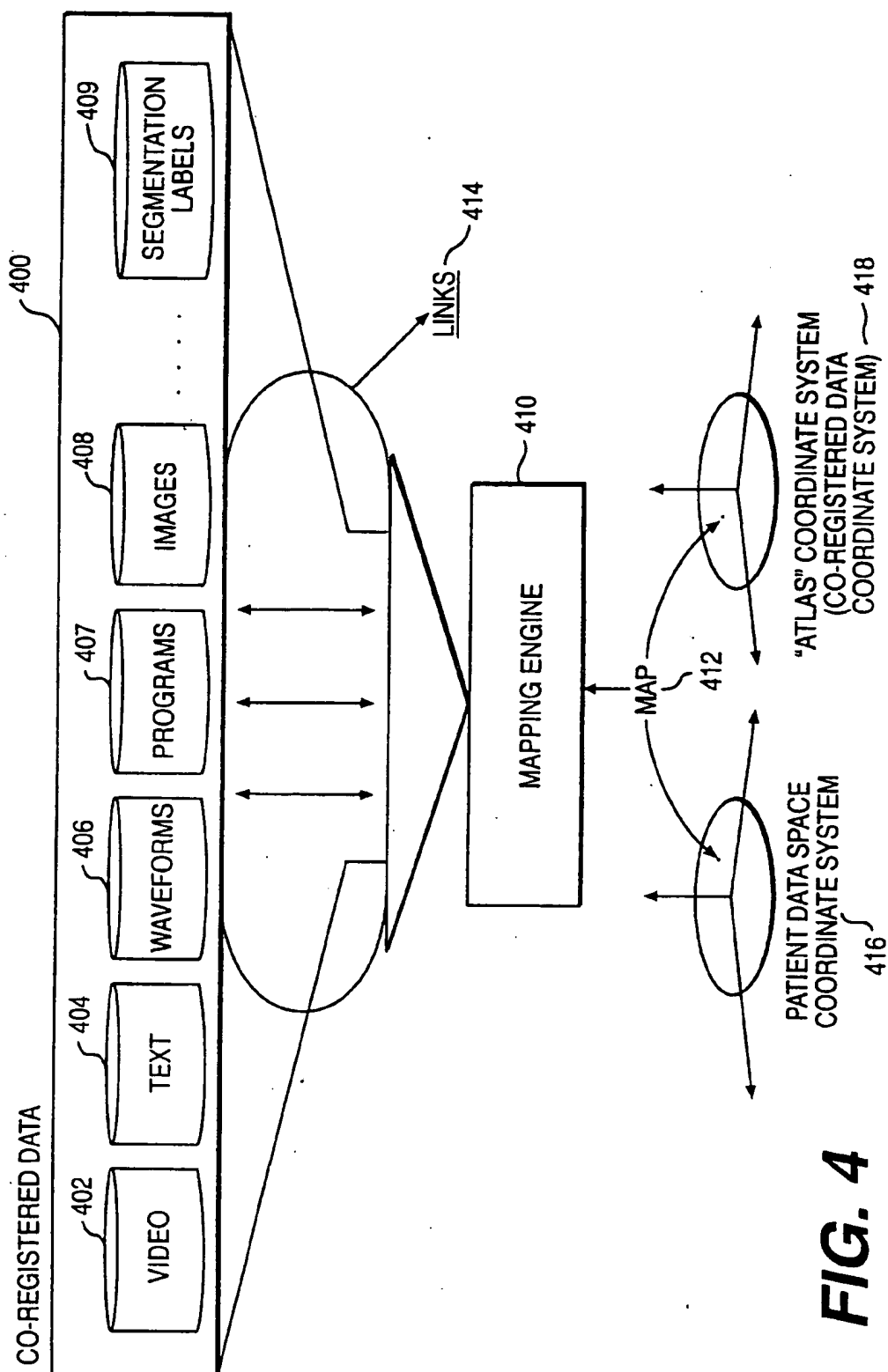
## OTHER PUBLICATIONS

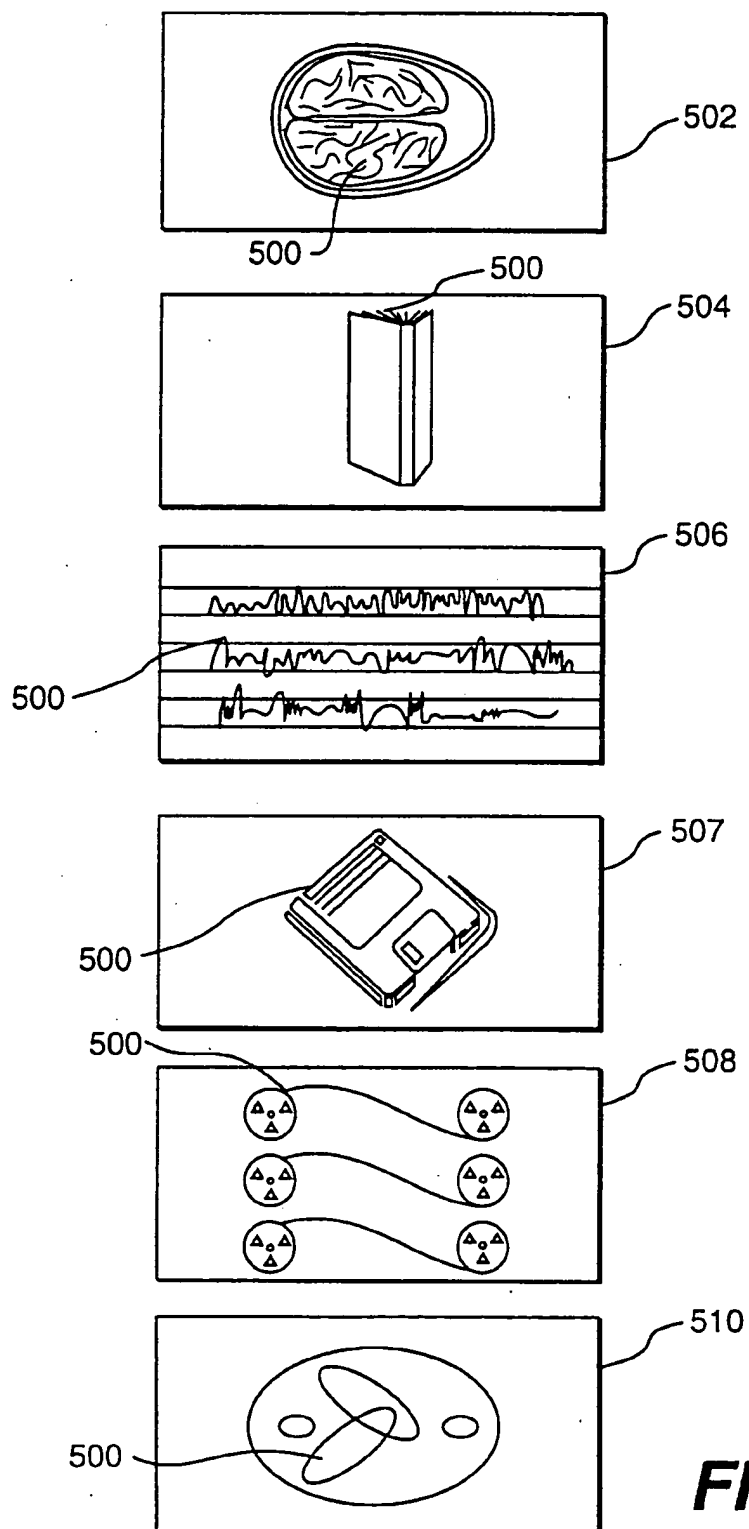
- Penn, et al., Stereotactic Surgery with Image Processing of Computerized Tomographic Scans, *Neurosurgery*, vol. 3, No. 2, 1978, pp. 157-163.
- Rosenman, et al., Three-Dimensional Display Techniques in Radiation Therapy Treatment Planning, *Int'l. Journal of Radiation Oncology Biology, Physics*, Jan. 1989, pp. 263-269.
- Davis, et al., Three-Dimensional High-Resolution Volume Rendering (HRVR) of Computer Tomography Data: Applications to Otolaryngology—Head and Neck Surgery, *Laryngoscope*, Jun. 1991, pp. 573-582.
- Rosenman, et al., Vistanet: Interactive Real-Time Calculation and Display of 3-Dimensional Radiation Dose: An Application of Gigabit Networking, *International Journal of Radiation Oncology Biology, Physics*, Jan., 1993, pp. 123-129.
- Heinz, et al., Examination of the Extracranial Carotid Bifurcation by Thin-Section Dynamic CT: Direct Visualization of Intimal Atheroma in Man (Part 1), *American Journal of Neuroradiology*, Jul./Aug. 1984, pp. 355-359.
- Hatch, Reference-Display System for the Integration of CT Scanning and the Operating Microscope, Master of Engineering Thesis, Dartmouth College, Hanover, N.H., Oct. 1984.
- Christensen et al., "Individualizing Neuro-anatomical Atlases Using a Massively Parallel Computer," IEEE (1996).
- Galvin, Jeffrey R., et al., "Image Corner, The Virtual Hospital, Providing Multimedia Decision Support Tools via the Internet," *SPINE*, vol. 20, No. 15, pp. 1735-1738, 1995.
- "The Electronic Clinical Brain Atlas: Three-Dimensional Navigation of the Human Brain," Thieme, Apr. 1996.
- Pelizzari, Charles A., "Accurate Three Dimensional Registration of CT, PET, and/or MR Images of the Brain," *J. of Computer Assisted Tomography*, vol. 13, No. 1, pp. 20-26 (Jan.-Feb. 1989).
- Gramkow, Claus, "Registration of 2D and 3D Medical Images," Lyngby, IMM-EKS-1996-1, (Jan. 1996).
- PCT International Search Report, Nov. 14, 1997.

**FIG. 1**



**FIG. 3**

**FIG. 4**

**FIG. 5**

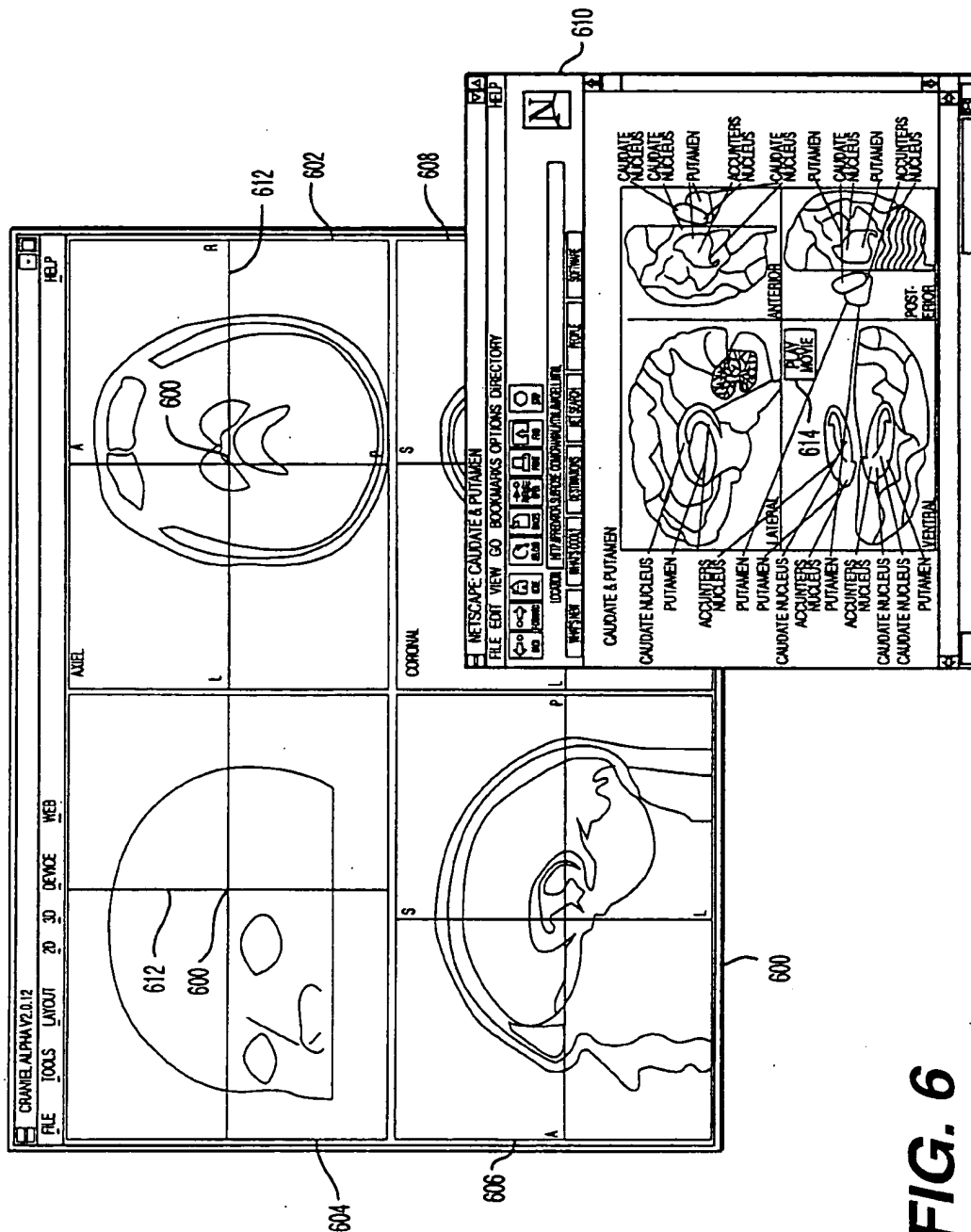
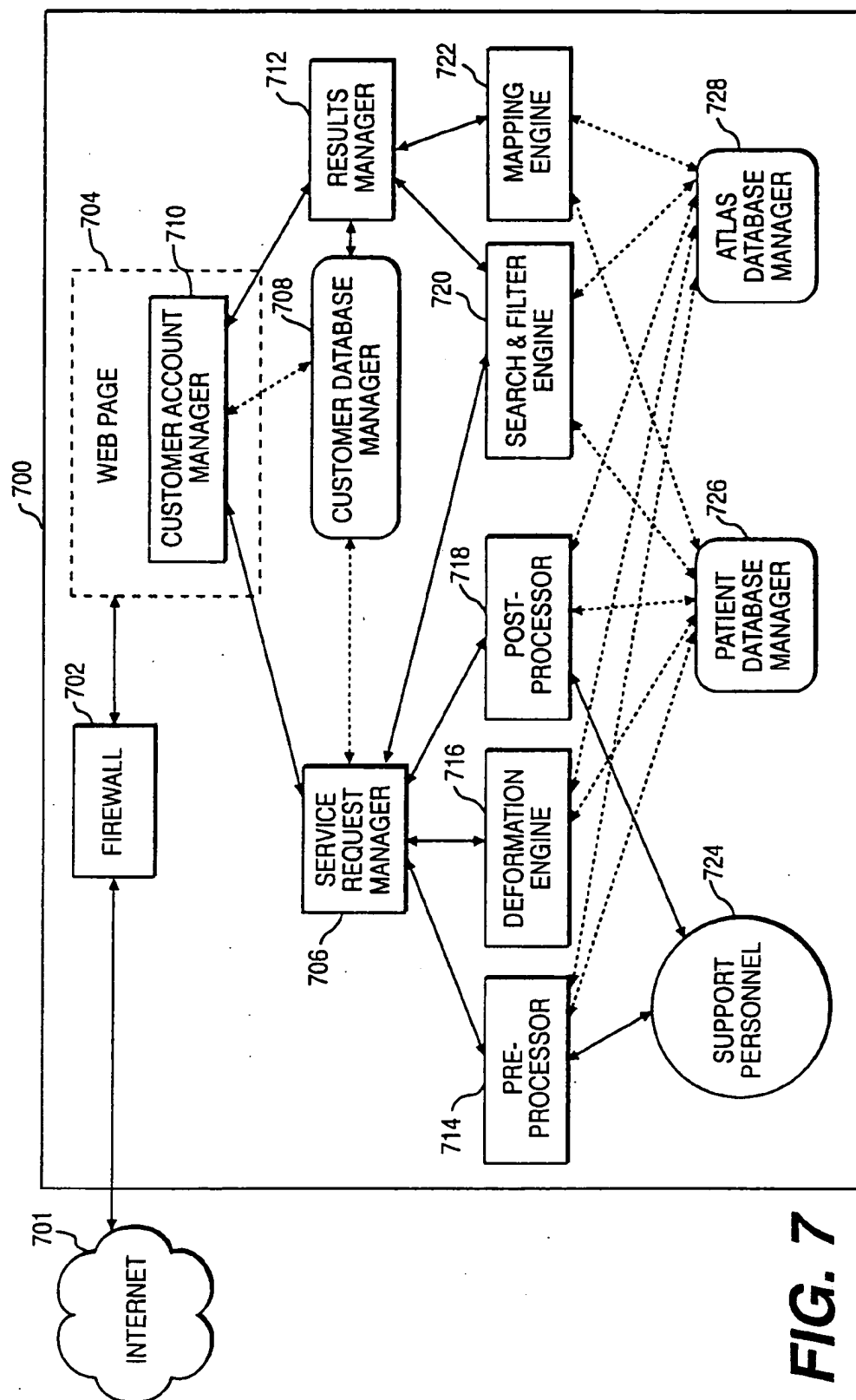


FIG. 6



**FIG. 7**

## METHOD AND APPARATUS FOR PRODUCING AND ACCESSING COMPOSITE DATA

### BACKGROUND OF THE INVENTION

The present invention relates to information systems and methods, and more particularly to data fusion systems.

Many applications require the contemporaneous assimilation of large amounts of data. Medical, military, and commercial applications require operators to engage in procedures and make decisions based on data describing various subjects represented by, for example, images, recorded sound, and text. Current technology does not present personnel with a unified view of this subject data to allow them to use all available data to make informed decisions.

For example, a physician providing medical treatment, reviews image data acquired in multiple modalities, such as magnetic resonance ("MR"), computed tomographic ("CT"), and X-ray images, medical journals describing procedures, video images, such as ultrasound, and atlases describing anatomical structures. A physician must therefore consult several sources to review the data necessary to provide patient treatment. These sources may include multiple computer display terminals located in different parts of a hospital, hard copies of medical images printed on film archived among thousands of images in a hospital film library or remote storage site, and volumes of journals located in the stacks of a hospital library. Also, the sources of data consulted by treating physicians may include medical atlases containing thousands of MR and CT scans of a cadaver corresponding to photographic images of cross-sectional slices taken of various anatomical structures.

Usually data from these atlases and other sources are not correlated with each other. A cadaver image in an atlas does not usually have the same geometry as a patient receiving treatment, so a physician must mentally fuse the available data which requires correlating the data retrieved from the various sources to develop a treatment plan or to provide information during medical procedures. The difficulties of fusing all of the available data increase if the physician must assimilate the various data types while rendering treatment.

The World Wide Web ("WWW") has recently made vast amounts of data stored on local and remote computers easily accessible through a graphical computer interface. The WWW is a network of computers, connected by the Internet, sharing a common file structure and mark-up language for creating files. The two most prevalent languages used to create multimedia WWW files are the hypertext mark-up language ("HTML") and the virtual reality mark-up language ("VRML"). HTML is best suited for creating files with text and two-dimensional image data, whereas VRML is designed for creating files containing images of three-dimensional objects. Both languages provide an easy way to combine image, text, and sound data in files accessible by "point-and-click," computer mouse driven user interfaces called "browsers."

A "browser" is a computer program that provides users access to files stored on the WWW. The browser displays files on a computer screen and can run programs, known as "applets," indicating links to data in other files on the WWW by, for example, underlining text or highlighting areas of an image. By selecting the underlined text or a highlighted image, the browser retrieves the linked data, allowing a user to view data stored on computers in the WWW without needing to know where the information is physically stored.

Files can be joined using these "hyperlinks," which give the name of the file along with an address for a computer storing the file. For example, the text or an image in a file stored on a computer in Switzerland can contain an embedded link to data stored on a computer in the United States. The WWW browser automatically recognizes the linked file data type, so the linked file can be an image, an audio clip, a video, or even an executable computer program. For example, if the linked data is an audio clip, the browser will load a program that takes the audio clip and plays it through the speakers of the user's computer. A browser usually runs on a computer referred to as a "client," while a computer known as a "server" hosts and produces WWW files requested by a client.

In particular, the WWW serves as a useful tool for navigating through two- and three-dimensional image data. For example, an image can be displayed by the browser, and different parts of the image can be linked to different files. But, for the most part, this WWW capability is primarily used for providing simple menus of uncorrelated data available on WWW computers. For example, a WWW computer will show an image of people, cars, and boats. By clicking on the image of people, a user can go to on-line chat sessions with people, or by clicking on a boat image, a user gets information about boats.

The current technology is limited because there does not exist an information system that exploits the data navigation capabilities of the WWW to correlate data retrieved from diverse sources and then assimilate the data into a useful form. For example, the tools available for information gathering in the WWW environment include database search engines and expert systems that assist a user in describing the information sought. However, these tools only retrieve files corresponding to a particular term or pertaining to certain designated subject matter. The retrieved files are not correlated with one another.

There is, therefore, a need for an information system that harnesses the power of the technology associated with the WWW and other similar image-based information retrieval systems to produce assimilated composite data in a form that operators can readily use.

### SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for producing and accessing composite data containing co-registered and subject data. The method for automatically producing composite data includes several steps, performed by a server computer. The steps include: creating a mapping relationship between the co-registered data and the subject data by mapping or deforming a template to fit the subject data; filtering the co-registered data; and producing composite data by mapping the filtered co-registered data to the subject data according to the mapping relationship.

A method consistent with this invention is also directed to steps, performed in a client computer, including: requesting composite data from a server computer; transmitting the subject data to the server computer; receiving the requested composite data from the server computer; presenting the received composite data to an operator; and monitoring the operator's use of composite data.

An apparatus consistent with this invention for automatically producing composite data containing co-registered data and subject data includes: structure for creating a mapping relationship between the co-registered data and the subject data by mapping or deforming a template to fit the subject data; structure for filtering the co-registered data;

and structure for producing composite data by mapping the filtered co-registered data to the subject data according to the mapping relationship.

Another apparatus consistent with the present invention automatically presents an operator with composite data containing co-registered data and subject data. Such an apparatus includes: structure for requesting composite data from a server computer; structure for transmitting the subject data to the server computer; structure for receiving the requested composite data from the server computer; structure for presenting the received composite data to an operator; and structure for monitoring the operator's use of the received composite data.

Both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

### DESCRIPTION OF THE FIGURES

The accompanying drawings provide a further understanding of the invention. They illustrate embodiments of the invention and, together with the description, explain the principles of the invention.

FIG. 1 is a block diagram of an apparatus for automatically producing composite data containing co-registered data and subject data consistent with the present invention;

FIG. 2 is a block diagram of another apparatus for automatically producing composite medical data containing co-registered medical data and patient data consistent with the present invention;

FIG. 3 is flow diagram of a method for automatically producing composite data containing co-registered data and subject data consistent with the present invention;

FIG. 4 is a schematic diagram of user interaction with the embodiment of the invention shown in the block diagram of FIG. 2;

FIG. 5 is an illustration of co-registered medical data used in an embodiment of the present invention consistent with the block diagram of FIG. 2;

FIG. 6 is a display produced in accordance with the embodiment of the present invention shown in the block diagram of FIG. 2; and

FIG. 7 is a block diagram of a facility for providing composite data in accordance with an embodiment of the present invention.

### DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to the preferred embodiments of this invention, examples of which are illustrated in the accompanying drawings.

To illustrate the principles of this invention, FIG. 1 shows subject data 100, template layer 102, deformation engine 104, mapping engine 106, map 107, filtered, co-registered data 108, search and filter engine 110, links 112, and co-registered databases 114. The term "layer" denotes a grouping of data types represented in, for example, a database on a server computer. To produce composite data 109, deformation engine 104 deforms a template layer 102 to fit subject data 100 generating map 107. When subject data 100 is multi-modal, multiple template layers can be utilized to correlate co-registered data 114 to subject data 100 as well as to correlate multi-modal subject data 100 to itself. A template layer contains reference data locations, or

landmarks, used to correlate template data with elements of subject data. Examples of landmarks include data representing points, lines, surfaces, volumes, or other defining features in image data.

Generally, deformation is the process of mapping one image to another image where both images represent the same structure but have different geometric proportions and orientations. During deformation, mathematical transforms are applied to the images that perform the equivalent of bending, stretching, and rotating template data to match subject data. For example, after deformation, template data in the form of a volume image of a generalized model of the human brain is manipulated so that the anatomical structure in this model has the same size, shape, and orientation as the subject data, the actual anatomy of a patient receiving treatment. There are many techniques available for automatically deforming one set of data to fit a target data set, including rule-based morphology, correlation of selected landmarks in each data set, and a technique fusing selected landmarks and image data. One example of such technique appears in U.S. patent application Ser. No. 08/678,628 filed Jul. 10, 1996, which is herein incorporated by reference.

Once template layer 102 is deformed to fit subject data 100, a mapping relationship, map 107, is established whereby mapping engine 106 maps co-registered data 114 to subject data 100 producing composite data 109. Co-registered data 114 represents a knowledge base providing supplemental information about structures contained in subject data 100. The co-registered databases and template layer share a common coordinate system, so a data element representing a position in one co-registered database is correlated with a data element representing that same position in each of the other co-registered databases. In an embodiment consistent with the present invention, co-registered data 114 is co-registered using, for example, the deformation techniques described above. The mapping relationship obtained from deforming template layer 102 to fit subject data 100 correlates the co-registered database coordinate system with a subject data coordinate system. Implementing this mapping relationship, mapping engine 106 relates points in the subject data coordinate system to corresponding points in the co-registered database coordinate system, providing a dynamic connection between subject data 100 and co-registered databases 114.

Search and filter engine 110 controls which elements of co-registered data 114 are mapped to subject data 100 and presented to an operator. Search and filter engine 110 can allow mapping engine 106 to map all or a subset of co-registered data 114 to subject data 100. Links 112 specify relationships among data elements across co-registered databases 114 which are used by search and filter engine 110 to assimilate co-registered data according to a service request by an operator including, for example, an indication of a region or regions of interest in subject data 100. The links 112 may be formed using an appropriate database indexing strategy to assign key-word or concept search tags to associated data elements.

FIG. 2 shows a preferred embodiment of the present invention for producing composite patient data for medical treatment. Collected patient data 200, includes, for example, MR image 236, CT image 238, and landmarks 240. Template layer 202 includes corresponding MR image 230, CT image 232, and landmark 234 templates. This embodiment also includes a deformation engine 204, mapping engine 206, search and filter engine 210, links 212, and co-registered data 214.

Co-registered data 214 includes a medical atlas 228, text 226, computer programs 225 (such as applets), labels and

landmarks 224, images 222, audio and video clips 220, links to computers located on the WWW 218, and treatment plans 216. Co-registered data can also include co-registered subject data. The foregoing list of co-registered data types is only provided as an example of the types of data that are useful in practicing this invention in the context of providing medical treatment. Persons of ordinary skill will recognize that many other data types may also be useful. One of ordinary skill in the art will also recognize that two or more of the co-registered data types may reside in a single database.

FIG. 3 is a flow diagram of a method for producing composite medical data consistent with the invention. An operator of a system consistent with this invention wishing to have composite data for medical treatment first identifies and possibly collects patient data 200 using a client computer (step 300). The collected patient data must have a modality (e.g., CT, MR, or X-ray) and protocol (e.g., slice thickness and resolution) that is compatible with a template in template layer 202.

The client computer then generates request 246 for composite data 244 (step 304). Request 246 includes, for example, an operator identifier, security screening information, and treatment information. The client computer also transmits or enables transmission of (from a radiological database, for example) collected patient data 200 and associated filtering context 242 to the server computer (step 306).

Responding to client computer request 246 for composite data 244, the server computer selects a template conforming with this request (step 308). Example template, MR 230, employed by the present invention when used for medical treatment includes a three-dimensional MR scan of the same slice thickness, resolution, and collection protocol as the patient MR dataset 236. Associated with the selected template imagery is a set of landmarks 234 identifying anatomical structures in a region of interest for a particular surgical procedure. Next, deformation engine 204 fits the selected template to patient data received from the client computer. The process of deforming the selected template to fit the patient data 200 creates a mapping relationship (map 248) relating template data space to a patient data space coordinate system (step 310). Mapping engine 206 also uses map 248 to relate a point in the patient data space coordinate system to an element of co-registered data 214. Once the mapping relationship is determined by deforming the selected template, all co-registered data 214 can be mapped to patient data 200. Note that if multi-modal patient data is used with multiple corresponding templates, multiple maps 248 can be constructed that can then be used to correlate the multi-modal patient data with each other in addition to correlating co-registered data 214.

Search and filter engine 210 controls how much of co-registered data 214 is included in the composite data. One reason for such control is that certain data types and/or data elements in co-registered data 214 may not be relevant for some medical treatment. Search and filter engine 210 responds to filtering context 242 and selects co-registered data elements as appropriate for this filtering context (step 312) using links 212 to identify related data elements. The filtering context can be derived from data provided by the client computer during the initial request for composite data (step 304). A filtering context can also be derived from previously stored profiles or histories. The server then produces composite data using mapping engine 206 and map 248 to combine patient data and filtered, co-registered data (step 314), producing composite data 244. The server then

transmits composite data 244 and map 248 to the client computer for presentation to an operator (step 318). The operator navigates the composite data by specifying a region of interest in the patient data using a browser interface (step 320). The operator may also use the browser interface to select highlighted text or other specified segments of the composite data, activating a link to a particular region of interest in the patient data.

Map 248 also allows an operator to access additional composite data (step 322). The server receives a request for additional co-registered data and preferably an associated position in the patient data coordinates from the client and subsequently retrieves and transmits additional co-registered data using mapping engine 206, map 248, search and filter engine 210, and links 212 to additional co-registered data 214. (repetition of steps 312-320).

An embodiment consistent with the present invention for use in the medical field links a radiologist's report to radiological imagery of a patient. Preferably, in an area of the radiologist's text report stating, for example, "in the left parietal-occipital region is a 1.2 cm hypodense lesion with an irregular border that does not enhance on contrast but is hyperintense on T2 . . .", selecting the highlighted word "lesion" activates a link to the patient imagery which highlights the particular sub-region discussed in the report text. Likewise, if the operator selects the lesion site in the displayed patient imagery, the link will be activated to display the section or sections of the text report that discuss the selected region of interest.

Although the foregoing description of embodiments of the present invention specifically allocate certain operations to client and server computers, one of ordinary skill in the art will recognize that the distribution of specific tasks between client and server computers can vary based on application requirements. Moreover, embodiments of the present invention with several client or server computers are within the scope of this invention. Furthermore, it is also consistent with the present invention that the client and server tasks can be performed in a single computer.

In a preferred embodiment of the present invention, a graphical user interface designed for browsing data presents composite data 244 to the operator. The interface is preferably executed on networked computers. Computer program code that can be adapted to perform this browsing function includes Internet browsers designed to navigate the WWW, such as Netscape's Navigator and Microsoft's Explorer, and equivalent programs that support links to data stored on networked computers.

FIG. 4 illustrates operator interaction associated with producing composite data in accordance with an embodiment of the present invention. FIG. 4 shows a database containing co-registered data 400 of several data types, including video 402, text 404, waveforms 406, programs 407, still images 408, and segmentation labels 409; a mapping engine 410; a map 412; a set of links 414 among associated data elements across and within the co-registered databases; a patient data space coordinate system 416; and a universal ("atlas") coordinate system 418 common to all data stored in co-registered database 400. A physician using this embodiment of the present invention selects any point in patient data space coordinate system 416 to retrieve co-registered data 400 corresponding to the selected point.

In an example illustrating co-registered data in one embodiment of the invention, still image database 408 contains MR images of a human head, database 406 contains recordings of waveforms produced by certain electrical

signals in the brain, video database 402 contains recorded motion picture images of neurosurgical procedures or tutorials for these procedures, text database 404 contains short descriptive paragraphs or full journal articles describing regions of the brain and related surgical plans, database 407 contains programs for processing image data, and database 409 contains segmentation maps outlining brain structures.

The patient data space coordinate system 416 is a frame of reference for patient specific data. This coordinate system is provided by, for example, an MRI of a patient's head or the surgical field surrounding the patient during operation. Deformation engine 204 computes a mapping relationship relating template layer data points in atlas coordinate system 418 to patient data points in patient data space coordinate system 416. Mapping engine 410 uses this computed mapping relationship to transform co-registered data 400 mapped to atlas coordinate system 418 to patient data space coordinate system 416.

After mapping, a physician has available during a surgical procedure composite data adapted to the patient's anatomy. This composite data is a representation of (1) a patient's anatomy comprising patient specific data acquired before or during a medical procedure, and (2) data from one or more of the co-registered databases 400.

Map 412 provides a virtual grid overlaying the patient data space coordinate system 416 allowing an operator to position a pointing device in the patient data to retrieve co-registered data. Selecting a position in map 412 retrieves co-registered data correlated with the selected position by mapping engine 410 through links 414.

In one embodiment of the invention, map 412 contains a number of positions corresponding to the number of positions in patient data space coordinate system 416 detectable by a surgical navigation system (see, e.g., U.S. Pat. No. 5,383,454). A map position is selected according to the location of a surgical probe in patient data space coordinate system 416 during a medical procedure. For example, during neurosurgery a surgeon placing the probe at a patient's ventricle activates a map position corresponding to the probe position in the ventricle. The activated map position is communicated to mapping engine 410 which queries co-registered databases 400 for data corresponding to the map position in the ventricle. This corresponding co-registered data is deformed to fit the patient's anatomy and combined with patient specific data giving the surgeon composite data related to the patient's ventricle, containing more information than the patient data alone.

A further illustration of the types of data a physician may require during neurosurgery or during surgical planning is shown in FIG. 5. This figure contains illustrations of five data types available to a surgeon in an embodiment of the present invention including a cross-sectional image 502, a medical journal article 504, electroencephalograph waveforms 506, computer programs 507, video images of the brain 508, and a segmentation map identifying the different regions of the brain 510. Because these data sources have been co-registered to a common atlas coordinate system, a point, such as point 500 in the cerebellum in brain image 502 from database 408, has a corresponding point in each of the other data types in co-registered database 400. For example, point 500 in text database 404 corresponds to article 504 on new surgical techniques involving the cerebellum. Point 500 in waveform database 406 corresponds to recorded waveforms 506 produced by the brain at this location. Point 500 in program database 407 corresponds to applet program 507, which is used to provide enhanced visualization of brain

image 502. Point 500 in video database 402 corresponds to video clips 508 of the brain at this location. Point 500 in segmentation map database 409 corresponds to a point within segmentation map 510.

Each of these examples of data need not be acquired from the patient currently receiving treatment. For example, the data may come from digital anatomical atlases, libraries of cadaver images, or research databases produced by projects such as the "Visible Human" research sponsored by the National Library of Medicine. Data available in a co-registered database would include, for example:

1. Anatomic

- Magnetic Resonance Imaging
- Computed Tomography
- Magnetic Resonance Angiography
- Ultra-Sound
- Slice photographic images
- Sulci/Gyri traces

2. Functional

- Positron Emission Tomography
- Single Photon Emission Computed Tomography
- Functional Magnetic Resonance images
- Electroencephalograph
- Magnetoencephalography

3. Symbolic

- Structure name
- Structure size
- Structure function
- Structure related text cues
- Structure related video cues
- Structure related audio cues
- Structure related labels
- Histology
- Morphological data

4. Multimedia

- Video Footage of procedures
- Training Videos
- Conference, Journal Articles
- Statistics

5. Computer Programs

- Applets
- Data Analysis
- Automated Structural Segmentation
- Image Enhancement and Visualization

These data need not be located in a single database. One of ordinary skill in the art will recognize that individual co-registered databases may be distributed among several databases accessible through, for example, local area computer networks or wide area computer networks connecting local and distributed computers. The combination of the different data components of the co-registered databases produces a generic data model of human anatomy where each data element is correlated through a common coordinate system with corresponding data elements of other types. When planning or providing medical treatment, the invention produces composite data linking co-registered data of a generic model to the specific anatomy of a patient

receiving treatment. Examples of other embodiments consistent with the present invention for producing composite data for medical diagnosis, planning, and treatment include, but are not limited to, the following.

1. Diagnostic Radiology—co-registered patient magnetic resonance, X-ray, and/or computed tomography imagery are linked to text data such as radiologists' reports, patient case history files, and relevant conference/journal articles. Sequential scans of a patient are co-registered for tracking the growth or reduction of lesions. Data analysis programs are linked to the composite data for computation of quantitative data measurements for planning and monitoring of treatment progress. Co-registered multi-modal patient image data and relevant co-registered data are presented in a common, easy-to-use presentation scheme.
2. Radiation Treatment Planning—Three-dimensional segmented atlases are mapped to patient data to produce an object-based model of lesions, targets, and major organs and other critical structures. The patient data with associated object information is utilized by a treatment planning program for computing optimized radiation delivery strategies from target and critical structure information.
3. Neurosurgical Targeting—cranial patient imagery is mapped to neurosurgical atlas information containing coordinates and shapes of surgical targets and surrounding neuroanatomic structures. Structural information is linked to audio files for use in surgery with microrecording probes. Links to statistical databases provide information relating regions of interest to procedures and success rates.

FIG. 6 shows how one embodiment of the present invention presents composite data to an operator on a computer display having several windows. Window 604 contains patient data in the form of a three-dimensional MR brain scan. Windows 602, 606, and 608 contain axial, sagittal, and coronal photographic section data, respectively, from the Visible Human data set, which are co-registered to the patient data by deformation engine 204. Window 610 presents co-registered atlas data to an operator. By positioning cross-hairs 612 in Window 604 at a desired point 600, the corresponding point 600 in each of the images in windows 602, 606, and 608 is identified automatically by the location of cross-hairs in those windows. Here, for example, the operator selected point 600 in window 604 corresponding to a region of the brain known as the putamen. Atlas data containing views of the putamen are displayed in window 610 with highlighted pointers indicating the putamen in each of the atlas images. The operator can also choose to play a movie showing video images of the putamen by pushing "play movie" button 614. Alternatively the operator may select the word "putamen" in window 610 and cross-hairs 612 will indicate the position of the putamen in patient data window 604 and the Visible Human "atlas" data windows 602, 606, 608.

FIG. 7 is a block diagram of a facility consistent with the present invention for providing composite data across a computer network to customers under a service contract. In FIG. 7, solid lines indicate a path for both control and data flow and dotted lines indicate data flow only. Facility 700 is preferably connected to a wide area network, such as Internet 701, through firewall 702. Firewall 702 is a computer that monitors all data traffic into and out of facility 700 to prevent unauthorized access to the facility. World Wide Web page 704 provides a graphical user interface to access facility 700. Facility 700 also includes customer account

manager 710, which controls functions available to customers with service contracts authorizing access to facility 700.

User login authentication is performed by customer account manager 710 and control is passed to one of three processes, service request manager 706, customer database manager 708, or results manager 712 depending on the service that the customer chooses. Customers that wish to initiate a new request for composite data are passed to service request manager 706. After successful completion of a composite data request, the customer's account is billed and the status of any pending requests is provided. Customers that wish to view the composite data generated in response to the request are passed to results manager 712. Information pertaining to a customer's account (e.g., billing information, changing passwords, user preferences, etc.) may be obtained by submitting queries to customer database manager 708.

Service request manager 706 initiates service requests and controls the computational operations required for anatomic mapping. The progress of a service request is tracked and reported to customer account manager 710. Customer database manager 708 administers a database that contains customer account data (not shown). Customer database manager 708 is responsible for controlling and backing up the customer database and it also processes queries from customer account manager 710, service request manager 706, and results manager 712. Results manager 712 integrates the results generated by service request manager 706 with context-specific medical knowledge. Results manager 712 receives information from search and filter engine 720 and mapping engine 722 specific to application requirements. Some results may be provided as visual representations (e.g., mapped segmented structures in a brain image) while others may be expressed in numeric form (e.g., coordinates of a neurosurgical target).

Preprocessor 714 checks patient data associated with a service request to make sure that the patient data is in the correct format and that the service request is appropriate. Support personnel 724 confirm the check performed by preprocessor 714. Any inconsistencies or anomalies that are found are reported to service request manager 706. Similarly, post processor 718 checks the results of a service request. Support personnel 724 confirm the check performed by preprocessor 718. Any inconsistencies or anomalies that are found are reported to service request manager 706.

Facility 700 also includes deformation engine 716, search and filter engine 720, and mapping engine 722. Deformation engine 716 computes atlas-to-patient transformations requested by service request manager 706. Search and filter engine 720 processes customer, patient, and procedure contextual data and integrates relevant atlas information according to application requirements. Both results manager 712 and service request manager 706 initiate search and filter engine 720 operations. Following a request from results manager 712, mapping engine 722 applies the results of the deformation process mapping an atlas to the patient data.

Patient database manager 726 administers a database that contains patient data and corresponding transformations computed by deformation engine 716. Patient database manager 726 serves queries from deformation engine 716, search and filter engine 720, and mapping engine 722 and is also responsible for controlling and backing up the patient database (not shown).

Atlas database manager 728 administers a database that contains the atlas data (not shown). Atlas database manager 728 serves queries from deformation engine 716, search and filter engine 720, and mapping engine 722 and is also

## 11

responsible for controlling and backing up the atlas database. Atlas database manager 728 can also perform and/or manage the indexing of the co-registered data databases.

While there has been illustrated and described what are at present considered to be preferred embodiments and methods of the present invention, persons skilled in the art will understand that various changes and modifications may be made, and equivalents may be substituted without departing from the scope of the invention.

In addition, many modifications may be made to adapt a particular element, technique or implementation to the teachings of the present invention without departing from the central scope of the invention. For example, disclosed elements may be implemented in hardware, computer program code, or a combination of both hardware and computer program code. Moreover, elements depicted and described separately may be combined and implemented in a single element. Therefore, this invention is not limited to the particular embodiments and methods disclosed, but includes all embodiments falling within the scope of the appended claims.

We claim:

1. A method for automatically producing composite data containing co-registered data and subject data, comprising the steps, performed in a server computer having a mapping engine, a search and filter engine, and a deformation engine, of:

creating a mapping relationship between the co-registered data and the subject data by mapping or deforming a template to fit the subject data;

filtering the co-registered data; and

mapping the filtered co-registered data to the subject data according to the mapping relationship to produce the composite data.

2. The method of claim 1, wherein said co-registered data contains co-registered subject data.

3. The method of claim 1, wherein the step of mapping includes the substep of:

relating a point in a subject data space coordinate system to an element of co-registered data.

4. The method of claim 1, wherein the step of mapping includes the substep of:

relating an element of co-registered data to a point in a subject data space coordinate system.

5. The method of claim 1, wherein the method further includes the step of:

receiving a request for said composite data from a client computer.

6. The method of claim 1, wherein the method further includes the step of:

receiving a request, including a filtering context, for said composite data from a client computer.

7. The method of claim 1, further comprising the step of: communicating said composite data to a client computer.

8. The method of claim 1, further comprising the step of: communicating a map representing the relationship between said subject data and said co-registered data to a client computer.

9. The method of claim 1, further comprising the step of: filtering said co-registered data according to a filtering context.

10. A method for automatically presenting an operator with composite data containing co-registered data and subject data, comprising the steps, performed in a client computer, of:

## 12

requesting composite data from a server computer; transmitting subject data corresponding to a first subject to said server computer;

co-registering said subject data corresponding to the first subject with subject data corresponding to a second subject to produce said requested composite data;

receiving said requested composite data from said server computer;

presenting said received composite data to an operator; and

monitoring the operator's use of said received composite data.

11. The method of claim 10, wherein the presenting step includes the substep of:

displaying said received composite data as an image.

12. The method of claim 10, wherein the presenting step includes the substep of:

displaying said received composite data as text.

13. The method of claim 10, wherein the presenting step includes the substep of:

generating sound from said received composite data.

14. The method of claim 10, wherein the presenting step includes the substep of:

displaying said received composite data as a video clip.

15. The method of claim 10, wherein the presenting step includes the substep of:

executing a program included in said received composite data.

16. The method of claim 10, wherein the presenting step includes the substep of:

displaying said received composite data in a browser having a graphical operator interface.

17. An apparatus having a mapping engine, a deformation engine, and a search and filter engine for automatically producing composite data containing co-registered data and subject data, comprising:

means for creating a mapping relationship between the co-registered data and the subject data by mapping or deforming a template to fit the subject data;

means for filtering the co-registered data;

means for mapping the filtered co-registered data to the subject data according to the mapping relationship to produce the composite data.

18. The apparatus of claim 17, wherein said co-registered data contains co-registered subject data.

19. The apparatus of claim 17, wherein the means for creating a mapping relationship comprises:

means for relating a point in a subject data space coordinate system to an element of co-registered data.

20. The apparatus of claim 17, wherein the means for mapping further comprises:

means for relating an element of co-registered data to a point in a subject data space coordinate system.

21. The apparatus of claim 17, further comprising:

means for receiving a request for said composite data from a client computer.

22. The apparatus of claim 17, further comprising:

means for processing a filtering context; and

means for receiving a request, including a filtering context for said composite data from a client computer.

23. The apparatus of claim 17, further comprising:

means for communicating said composite data to a client computer.

## 13

24. The apparatus of claim 17, further comprising:  
 means for communicating a map representing the relationship between said subject data and said co-registered data to a client computer.

25. The apparatus of claim 17, wherein the means for producing composite data comprises:  
 means for filtering said co-registered data according to a filtering context.

26. An apparatus for automatically presenting an operator with composite data containing co-registered data and subject data, comprising:  
 means for requesting composite data from a server computer;  
 means for transmitting subject data corresponding to a first subject to said server computer;  
 means for co-registering said subject data corresponding to the first subject with subject data corresponding to a second subject to produce said requested composite data;  
 means for receiving said requested composite data from said server computer;  
 means for presenting said received composite data to an operator; and  
 means for monitoring the operator's use of said received composite data.

27. The apparatus of claim 26, wherein the means for presenting comprises:  
 means for displaying said received composite data as an image.

28. The apparatus of claim 26, wherein the means for presenting comprises:  
 means for displaying said received composite data as text.

29. The apparatus of claim 26, wherein the means for presenting comprises:  
 means for generating sound from said received composite data.

30. The apparatus of claim 26, wherein the means for presenting comprises:  
 means for displaying said received composite data as a video clip.

31. The apparatus of claim 26, wherein the means for requesting comprises:  
 means for browsing data stored on a computer presented to the operator in a graphical form.

32. The apparatus of claim 26, wherein the means for presenting comprises:  
 means for browsing data stored on a computer presented to the operator in a graphical form.

33. The apparatus of claim 26, wherein the means for presenting comprises:  
 means for executing a program included in said received composite data.

34. A method for automatically producing composite medical data containing co-registered medical data and patient data, comprising the steps, performed in a server computer having a mapping engine, a search and filter engine, and a deformation engine, of:  
 creating a mapping relationship between the co-registered medical data and the patient data by mapping or deforming a template to fit the patient data;  
 filtering the co-registered medical data; and  
 mapping the filtered co-registered medical data to the patient data according to the mapping relationship to produce the composite medical data.

## 14

35. The method of claim 34, wherein said co-registered medical data contains co-registered patient data.

36. The method of claim 34, wherein the step of mapping includes the substep of:  
 relating a point in a patient data space coordinate system to an element of co-registered data.

37. The method of claim 34, wherein the step of mapping includes the substep of:  
 relating an element of co-registered medical data to a point in a patient data space coordinate system.

38. The method of claim 34, wherein the method further includes the step of:  
 receiving a request for said composite medical data from a client computer.

39. The method of claim 34, wherein the method further includes the step of:  
 receiving a request, including a filtering context, for said composite medical data from a client computer.

40. The method of claim 34, further comprising the step of:  
 communicating said composite medical data to a client computer.

41. The method of claim 34, further comprising the step of:  
 communicating a map representing the relationship between said patient data and said co-registered medical data to a client computer.

42. The method of claim 34, further comprising the step of:  
 filtering said co-registered medical data according to a filtering context.

43. A method for automatically presenting an operator with composite medical data containing co-registered medical data and patient data, comprising the steps, performed in a client computer, of:  
 requesting composite medical data from a server computer;  
 transmitting patient data corresponding to a first patient to said server computer;  
 co-registering said patient data corresponding to the first patient with patient data corresponding to a second patient to produce said requested composite medical data;  
 receiving said requested composite medical data from said server computer;  
 presenting said received composite medical data to an operator; and  
 monitoring the operator's use of said received composite medical data.

44. The method of claim 43, wherein the presenting step includes the substep of:  
 displaying said received composite medical data as an image.

45. The method of claim 43, wherein the presenting step includes the substep of:  
 displaying said received composite medical data as text.

46. The method of claim 43, wherein the presenting step includes the substep of:  
 generating sound from said received composite medical data.

47. The method of claim 43, wherein the presenting step includes the substep of:  
 displaying said received composite medical data as a video clip.



## 15

48. The method of claim 43, wherein the presenting step includes the substep of:

executing a program included in said received composite medical data.

49. The method of claim 43, wherein the presenting step includes the substep of:

displaying said received composite medical data in a browser having a graphical operator interface.

50. An apparatus having a mapping engine, a deformation engine, and a search and filter engine for automatically producing composite medical data containing co-registered medical data and patient data, comprising:

means for creating a mapping relationship between the co-registered medical data and the patient data by mapping or deforming a template to fit the patient data;

means for filtering the co-registered medical data;

means for mapping the filtered co-registered medical data to the patient data according to the mapping relationship to produce the composite medical data.

51. The apparatus of claim 50, wherein said co-registered medical data contains co-registered patient data.

52. The apparatus of claim 50, wherein the means for creating a mapping relationship comprises:

means for relating a point in a patient data space coordinate system to an element of co-registered medical data.

53. The apparatus of claim 50, wherein the means for mapping further comprises:

means for relating an element of co-registered medical data to a point in a patient data space coordinate system.

54. The apparatus of claim 50, further comprising:

means for receiving a request for said composite medical data from a client computer.

55. The apparatus of claim 50, further comprising:

means for processing a filtering context; and  
means for receiving a request, including a filtering context for said composite medical data from a client computer.

56. The apparatus of claim 50, further comprising:

means for communicating said composite medical data to a client computer.

57. The apparatus of claim 50, further comprising:

means for communicating a map representing the relationship between said patient data and said co-registered medical data to a client computer.

58. The apparatus of claim 50, wherein the means for producing composite medical data comprises:

means for filtering said co-registered medical data according to a filtering context.

59. An apparatus for automatically presenting an operator with composite medical data containing co-registered medical data and patient data, comprising:

means for requesting composite medical data from a server computer;

means for transmitting patient data corresponding to a first patient to said server computer;

means for co-registering said patient data corresponding to the first patient with patient data corresponding to a second patient to produce said requested composite medical data;

means for receiving said requested composite medical data from said server computer;

means for presenting said received composite medical data to an operator; and

## 16

means for monitoring the operator's use of said received composite medical data.

60. The apparatus of claim 59, wherein the means for presenting comprises:

means for displaying said received composite medical data as an image.

61. The apparatus of claim 59, wherein the means for presenting comprises:

means for displaying said received composite medical data as text.

62. The apparatus of claim 59, wherein the means for presenting comprises:

means for generating sound from said received composite medical data.

63. The apparatus of claim 59, wherein the means for presenting comprises:

means for displaying said received composite medical data as a video clip.

64. The apparatus of claim 59, wherein the means for requesting comprises:

means for browsing data stored on a computer presented to the operator in a graphical form.

65. The apparatus of claim 59, wherein the means for presenting comprises:

means for browsing data stored on a computer presented to the operator in a graphical form.

66. The apparatus of claim 59, wherein the means for presenting comprises:

means for executing a program included in said received composite medical data.

67. An apparatus for automatically presenting an operator with composite medical data containing co-registered medical data and patient data, comprising:

a surgical navigation system for requesting composite medical data from a server computer;

means for transmitting the patient data to said server computer;

means for receiving said requested composite medical data from said server computer;

means for presenting said received composite medical data to an operator; and

means for monitoring the operator's use of said received composite medical data.

68. An apparatus for automatically presenting an operator with composite medical data containing co-registered medical data and patient data, comprising:

means for requesting composite medical data from a server computer;

means for transmitting the patient data to said server computer;

means for receiving said requested composite medical data from said server computer;

a surgical navigation system for presenting said received composite medical data to an operator; and

means for monitoring the operator's use of said received composite medical data.

69. A method for automatically presenting an operator with composite medical data containing co-registered medical data and patient data, comprising the steps, performed in a computer, of:

co-registering data corresponding to a first patient with data corresponding to a second patient producing composite medical data;

linking the composite medical data to text contained in a medical report;

17

receiving operator input selecting a word in said medical report; and

presenting to the operator said linked composite medical data corresponding to said selected word.

70. A method for automatically presenting an operator with text from a medical report corresponding to composite medical data containing co-registered medical data and patient data, comprising the steps, performed in a computer, of:

co-registering data corresponding to a first patient with data corresponding to a second patient producing composite medical data;

linking the composite medical data to text contained in the medical report;

receiving operator input selecting a point in an image representing the composite medical data; and

presenting to the operator said linked text corresponding to said selected point.

71. A method for automating diagnosis, planning treatment, or monitoring medical treatment progress using composite medical data containing co-registered medical data and patient data, comprising the steps, performed in a computer, of:

linking a data analysis computer program to the composite medical data;

computing a measure using said data analysis computer program; and

presenting said measure to an operator of said computer for use in diagnosis, planning treatment, or monitoring medical treatment progress.

18

72. A method for automating radiation treatment planning using composite medical data containing co-registered medical data and patient data, comprising the steps, performed in a computer, of:

mapping a three-dimensional segmented atlas to the patient data;

generating a model of an anatomical structure and a pathological structure in the patient data; and

generating a radiation treatment plan using said model.

73. A method for automatically selecting a target using composite medical data containing co-registered medical data and patient data, the co-registered data including a target atlas, comprising the steps, performed in a computer, of:

generating a map by deforming a template to said patient data;

creating target information by mapping said target atlas to said patient data using said map; and

presenting said target information to an operator of said computer for planning treatment.

74. A facility for providing composite data including subject data and co-registered data, the facility comprising:

a deformation engine for computing a data transformation responsive to a request for composite data;

a search and filter engine for extracting data from an atlas database; and

a mapping engine for mapping data extracted by said search and filter engine to said subject data.

\* \* \* \* \*